

Characterization of broiler cake and broiler litter, the by-products of two management practices

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Abstract

The application of broiler manure and bedding (litter) on land has been a long-used disposal method that benefits plant and soil. For proper manure management, factors such as nutrient content, house cleaning management, application methods, and many land, crop, and climatic factors must be considered. A study was undertaken to characterize broiler cake and broiler litter as the by-products of two management systems in Mississippi. Broiler cake and litter productions were quantified and analyzed for four flocks during 1999 and 2000. The overall means for broiler cake production were 12.50, 13.90, and 10.30 kg m⁻² for producers 1, 2, and 3, respectively. Significantly greater quantities of litter, 27.50, 29.0, and 28.30 kg m⁻² than cake were determined for the same producers. The cake and litter moisture averaged 455 and 277 g kg⁻¹, respectively. No significant differences were observed between cake and litter total N, NH₄-N, total C, total P, and water-soluble P (WP). However, cake had significantly greater Ca, Mg, K, Cu, Fe, Mn, and Zn than litter. Approximately 16.8% of the broiler cake and 15.2% of the broiler litter total P were in the form of water-soluble P. The NH₄-N content of the cake and the litter were 12.5% and 11.5% of the cake and litter total nitrogen, respectively. The results also showed the advantage of the decaking practice with respect to the quantity of the manure generated for land application. Approximately 57% of the litter remains in the poultry house with decaking practice after each growth cycle compared to the 0% for total cleanout practice.

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1. Introduction

Broiler chicken (*Gallus gallus domesticus*) production is the top farm commodity in many states in the southeastern region of the United States. The quantity of manure produced as a by-product of the broiler industry is substantial. For example, in 2000, the US broiler industry produced 7.2 billion broilers and generated about 10 million metric tons of litter (Georgia Agricultural Statistics Service, 1995). Poultry litter (manure plus bedding materials) can improve soil tilth, reduce soil compaction, and add organic matter and nutrients to increase soil fertility and productivity (Van Dyne and Gilbertson, 1978; Edmisten et al., 1992). Poultry litter can be applied either as fresh or composted manure (Eghball and Power, 1999; Kelling et al., 1995).

The return of manure to the land completes a natural recycling process. However manure is also known to be a potential source of pollution to the environment (White, 1979; Sommerfeldt and Chang, 1985; Mozafferi and Sims, 1994; Kingery et al., 1994; Robinson and Sharpley, 1995; Codling et al., 2000). The excessive land application leads to the build up of soil nutrient levels, especially phosphorus (P), and increases the potential for surface and groundwater pollution through runoff and leaching. Manure management is the critical factor that affects the value of this fertilizer resource (Stephenson et al., 1990; Tisdale et al., 1993).

Poultry producers must periodically clean their poultry houses to promote bird health and limit build up of wet manure. Historically, after 8–10 flocks (growth cycles of 47–49 d), the poultry house is cleaned to the ground level (total cleanout). Litter, which is a combination of manure, bedding materials, and spilled feed, is replaced with fresh bedding (wood shavings, pine needles, or peanut

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hulls). The litter is either applied directly to pasture or crop lands or stored for later application. The vast majority of the broiler producers no longer practice total cleanout in order to save money and labor. A more recent management practice called “decaking” involves the removal of the “cake”, which is fresh manure combined with bedding materials and spilled feed. In contrast with broiler litter, broiler cake is normally 5–10 cm thick and forms on the surface of bedding materials, with great variability throughout the poultry house. After each flock is harvested, the cake is separated from bedding materials by passing the cake and a portion of the dry bedding materials over a grate that allows the fine materials to pass through and return to the floor while collecting the larger aggregations of cake in a hopper. The separation of cake from litter is performed using specialized equipment, with the trade name of “Housekeeper®”, pulled by a tractor. With this new management practice, producers do not have to replace the entire bedding materials for many years; instead, periodically they add small quantities of fresh bedding to compensate for the amount removed with the cake.

There is a need for accurate characterization of the broiler cake, which is the by-product of the decaking compared to broiler litter (total cleanout), since most of the litter presently applied to land in Mississippi is cake. Therefore, the objective of this study was to quantify broiler cake production and determine the impact of producer management and broiler age on cake nutrient composition, as compared to broiler litter generated from the total cleanout practice. The information may be used as a guide for the management of broiler manure as a valuable plant nutrient resource while minimizing potential adverse environmental impacts.

2. Methods

2.1. Source of litter and caking materials

Three broiler producers from Smith and Leake Counties in Mississippi were selected as cooperators in this study. For our discussion in this paper, we refer to the three producers as producer 1 or 2 or 3. Producers 1 and 2 are contracted by the same integrator, hence using the same feed which is provided by the integrator, while producer 3 is contracted by a different integrator and uses different feed than producers 1 and 2. Each producer owns six poultry houses with the capacity of accommodating between 20 and 25 thousand birds per house. Producers 1 and 2 manage their poultry houses (113×12 m² each) with normal ambient lighting, while the third producer houses (146×13 m² each) are under a “blackout” system. Under the blackout system, birds are kept in 95% darkness to reduce their moving activities presumably enhancing the rate of weight gain. All

three producers practice decaking after each flock is removed from the houses (47–49 d). Usually cakes are left inside the houses for a few days to reduce the moisture content, which also facilitates the process of decaking.

2.2. Broiler cake quantification

Three broiler houses were selected randomly from each producer. Composite cake and litter samples were collected randomly from each area (front, middle, and end) of each broiler house four times per flock. The first sampling date was the day before the one or two-day old chicks were brought in to the house and considered the background sample for each flock. The second and third sampling dates occurred when the birds were 21 and 35 d old, and the fourth sampling took place shortly after the flock was harvested from the house (47–49 d). The sampling procedure was repeated for four flocks during a one year span from the same houses and producers. The broiler cake sampled at the fourth sampling date represented the actual cake materials used for land application. Cake and litter samples were cooled over ice in an ice chest and transported to the laboratory within 2–3 h. Subsamples were taken for moisture determination by drying in a forced draft oven at 65 °C for 48 h. After air drying in a ventilated glass-roofed greenhouse, broiler cake and litter samples were ground to pass a 1-mm screen prior to chemical analyses. We determined the quantity of cake and litter produced at each house for each producer after each flock was harvested. This was accomplished by isolating a 40-cm wide strip across the width of the poultry house at three different locations (front, middle, and end). The litter was collected from the surface to the ground and weighed as is (wet basis) to quantify the litter production. The cake was separated from the litter by passing the total collected litter from the isolated area through a custom made screen with openings of the same size (6.45 cm²) at the commercial decaker. All the materials that remained on the screen were considered broiler “cake”, which was weighed on “as is” basis for the determination of cake production.

2.3. Chemical analysis

The following chemical analyses were performed on cake and litter samples. The pH was measured in a 1:5 manure:water ratio using 2 g dry manure. Total N (TN) was measured by Kjeldahl digestion procedure with a salicylic acid modification (Bremner, 1976) and using a FOSS Kjeltac 3200 N analyzer. Cake and litter were extracted with 0.01 M KCl (1:15 manure:KCl) using 2 g dry manure, and analyzed for nitrate (NO₃-N) and ammonium (NH₄-N) using a Dionex-500 Ion Chromatograph (IC) (Keeney and Nelson, 1982). Approximate

mately 0.5 g cake or litter sample was ashed in a muffle furnace (Thermolyne Corporation 30400, Dubuque, Iowa) at 500 °C for 4 h. The ash was dissolved initially in 1.0 ml of 6 N HCl for 1 h, followed by 50 ml of a double acid solution of 0.025 N H₂SO₄ and 0.05 N HCl, and the mixture was allowed to stand for another hour prior to filtration (Southern Cooperative Series, 1983). The ashed samples were used for the following analyses: total phosphorus (TP), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) using a Thermo Jarrell-Ash Inductively Coupled Plasma Spectrophotometer (ICP Franklin, MA). Cake and litter samples were also extracted with deionized water (1:15 manure:water) using 2 g manure, shaken for 30 min, and filtered through 2 V Whatman brand filter paper for water extractable P (WP) and analyzed by ICP. The samples were not filtered through a 0.45 µm filter because our objective was to determine the total water extractable portion of P in the cake and litter rather than only the “soluble reactive” portion (Self-Davis and Moore, 2000). The experiment was considered as a nested design since broiler houses were nested in the producers, and the flocks were nested in the houses. The data were analyzed using the GLM procedure in SAS (SAS Inst., 1998). Tukey’s test was applied to treatment means at 0.05 probability level.

3. Results and discussion

Since there were significant differences among producers, results were reported separately as the averages of houses and flocks for each producer. However, grand

Table 1

Broiler cake and broiler litter production for three commercial broiler producers in Mississippi

Producer	Broiler cake ^a (kg/m ²)	Broiler litter (kg/m ²)	Cake moisture (g/kg)	Litter moisture (g/kg)
1	12.5 (1.1)a*	27.5 (1.7)b	440	256
2	13.9 (1.1)a	29.0 (1.8)b	448	278
3 ^b	10.3 (0.9)a	28.3 (1.8)b	477	297

Standard error in parentheses ($n = 12$); means followed by the same letter in each row for cake and litter (excluding moisture) are not significantly different at 0.05 probability level, Tukey’s test.

^a Cake, litter, and moisture are reported on as is (wet) basis.

^b Blackout system.

means were reported for general statements. The quantities of broiler cake produced for all broiler producers were significantly smaller than broiler litter. There were significant differences between cake and litter production per unit area for all producers (Table 1). Based on the calculation from data presented in Table 1, quantities of the broiler cake produced as a percentage of the broiler litter were 45.5%, 47.9%, and 36.4% for producers 1, 2, and 3, respectively. Thus, for any producer that manages the manure by decaking in lieu of total cleanout, approximately 57% (average of 3 producers) of the broiler litter remains in the poultry house, as compared to 0% for total cleanout practice. Based on the number of birds per house, the overall average of 0.90 kg cake per bird and 1.92 kg litter per bird was calculated for each growth cycle. These results indicate that a typical commercial broiler producer in Mississippi with six poultry houses accommodating approximately 120,000 birds (20,000/house) and managing the manure by total cleanout would generate about 230 metric tons

Table 2

Total carbon (TC), total nitrogen (TN), total phosphorus (TP), water-soluble phosphorus (WP), ammonium nitrogen (NH₄-N), nitrate nitrogen (NO₃-N) content and pH of the broiler cake, broiler litter, and broiler feed^a

Variables	pH	TC (g kg ⁻¹)	TN (g kg ⁻¹)	TP (g kg ⁻¹)	WP (g kg ⁻¹)	NH ₄ -N (g kg ⁻¹)	NO ₃ -N (g kg ⁻¹)
Broiler cake	7.4 (0.2)*	343 (20.2)	37.6 (3.8)	19.17 (1.2)	3.22 (0.4)	4.69 (0.6)	0.59 (0.7)
Broiler litter	7.6 (0.2)	320 (18.7)	32.8 (3.5)	18.77 (1.4)	2.86 (0.3)	3.77 (0.4)	0.29 (0.8)
Broiler feed	6.2 (0.1)	410 (16.6)	31.4 (2.4)	6.93 (0.8)	2.47 (0.1)	0.34 (0.01)	0.07 (0.01)

Standard error in parentheses; means in each column (excluding feed, which was not considered in the statistical analysis) were not significantly different at a $p < 0.05$ probability level according to Tukey’s test.

^a Data points are averages of 144 samples except for feed.

Table 3

Calcium (Ca), magnesium (Mg), potassium (K), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn) content of the broiler cake, broiler litter, and broiler feed^a

Variables	Ca (g kg ⁻¹)	Mg (g kg ⁻¹)	K (g kg ⁻¹)	Cu (mg kg ⁻¹)	Fe (mg kg ⁻¹)	Mn (mg kg ⁻¹)	Zn (mg kg ⁻¹)
Broiler cake	99.1 (8.7)a*	24.4 (2.1)a	125.7 (8.9)a	2763 (72)a	3818 (119)a	2307 (102)a	1848 (92)a
Broiler litter	26.2 (2.4)b	6.1 (0.9)b	30.3 (1.5)b	662 (43)b	1055 (57)b	556 (23)b	436 (27)b
Broiler feed	10.1 (1.3)	1.8 (0.3)	9.0 (1.1)	210 (19)	202 (18)	169 (14)	139 (11)

Standard error in parentheses; means followed by the same letter in each column (excluding feed, which was not considered in the statistical analysis) were not significantly different at a $p < 0.05$ probability level according to Tukey’s test.

^a Data points are averages of 144 samples except for feed.

of litter at the end of each flock. However, by practicing decaking instead of total cleanout, a producer would generate only 100 metric tons of cake at the end of each flock. This represents a 56.5% decrease in the total manure that needs to be disposed, which is substantial for a producer who raises on average 5–7 flocks per year.

There was no significant difference in pH, total carbon (TC), TN, TP, WP, $\text{NH}_4\text{-N}$, and $\text{NO}_3\text{-N}$ of broiler cake and broiler litter (Table 2). This is not surprising

because during the decaking process, usually small cake fractions pass through the grate and remain in the litter mix. Therefore, after one or two years (6–12 decaking processes) the litter becomes enriched with nutrients. However, broiler cake contained greater concentrations of Ca, Mg, K, Cu, Fe, Mn, and Zn than broiler litter, which may possibly be due to the spilled feed on the surface of cake materials (Table 3). There were significant differences among producers with regard to TN,

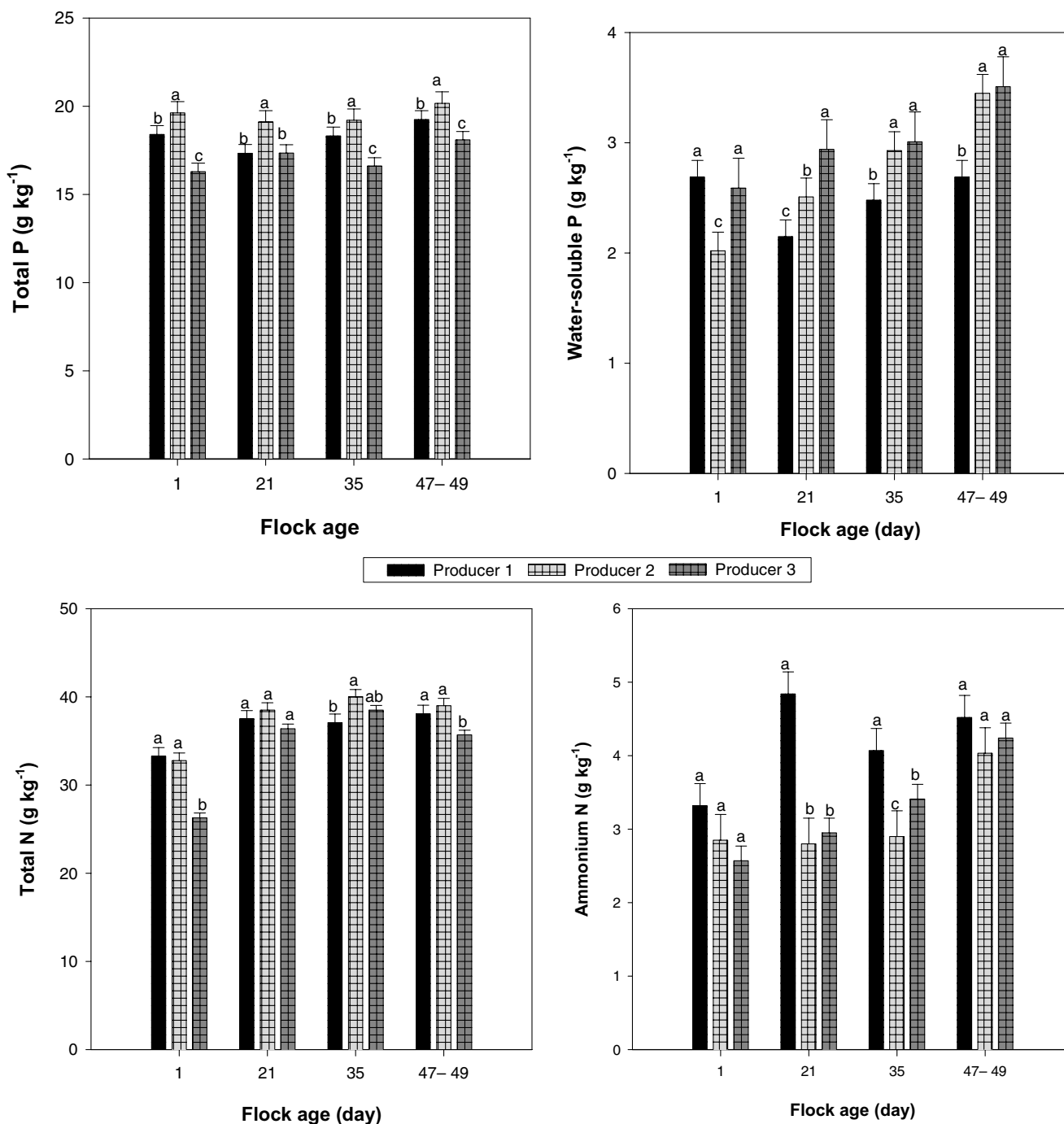


Fig. 1. Variation of total P, water-soluble P, total N, and ammonium N in broiler cake for each producer at different flock age. Data points are averages of three houses and four flocks.

TP, WP, and $\text{NH}_4\text{-N}$ at each sampling date without any specific trends which reflect the impact of different management practices on these parameters (Fig. 1). The TP and TN contents of broiler cake for producer 3 (blackout management) were significantly lower than for producers 1 and 2 for the background (1 d) and varied when the birds were 21, 35, and 49 d old (Fig. 1). However, the cake WP concentration for producer 3

was either similar to or significantly greater than those of producers 1 and 2. The TP content of broiler cake sampled when birds were 47–49 d old (decaking time) was 19.25, 20.18, and 18.10 g kg^{-1} for producers 1, 2, and 3, respectively. The broiler cake WP content was 2.69, 3.45, and 3.51 g kg^{-1} which corresponded to 14%, 17%, and 19% of the cake TP concentration at decaking time (calculated from Fig. 1). It is interesting that,

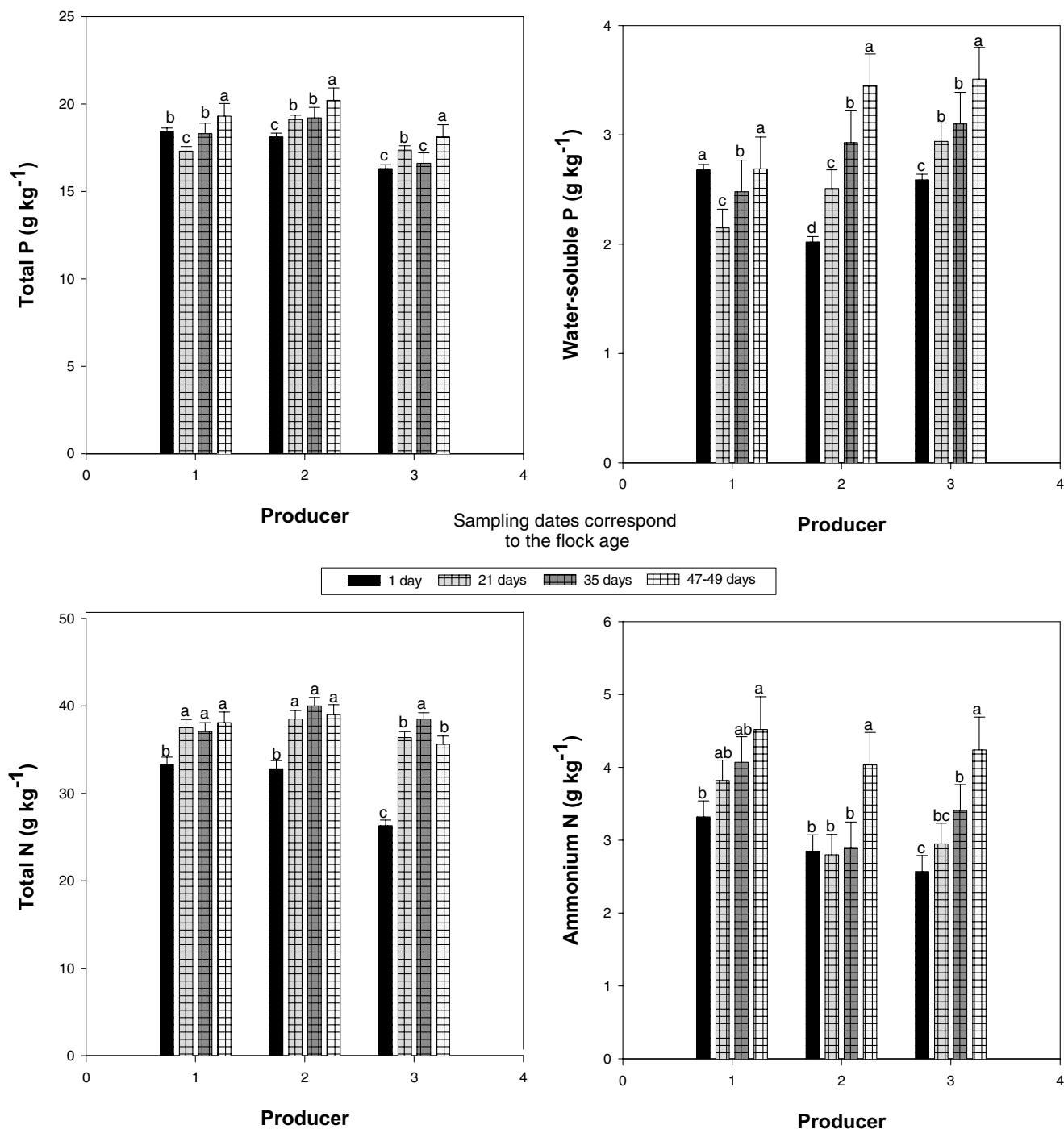


Fig. 2. Total P, water-soluble P, total N, and ammonium N content of broiler cake collected at different flock age. Data points are averages of three houses and four flocks for each producer.

broiler cake of producer 3 contained significantly lower TP than cake of producers 1 and 2, but contained significantly greater WP than producer 1 and was not significantly different than producer 2. Also calculating from Fig. 1, the cake TN concentration for producers 1, 2, 3 was 38.1, 39.0, and 35.7 g kg⁻¹, respectively, while the cake NH₄-N content was 4.52, 4.03, and 4.24 g kg⁻¹ which corresponded to 11.9%, 10.3%, and 11.9% of the cake TN, respectively.

In short, no particular trend in TN, NH₄-N, TP, and WP concentrations of cake samples taken at a different bird ages was observed across all flocks for each producer. For all producers, N content of broiler cake significantly ($p < 0.05$) increased between first and second sampling, but did not change thereafter for producers 1 and 2, while it increased to the third sampling date (35 d) for producer 3. However, the cake NH₄-N content increased significantly from first sampling (1 d) to the fourth sampling date (47–49 d) (Fig. 2). We speculate the increase in cake NH₄-N content from date 3 to 4 was due either to climatic changes, particularly moisture and temperature, or birds age. The broiler cake TP content for producer 1 decreased from first to second sampling then increased significantly to the fourth sampling date. The cake TP content at sampling date 4 was significantly greater than the other sampling dates for all producers. Broiler cake WP content for producer 1 decreased from sampling 1 to 2, and then increased significantly from sampling dates 3 to 4. The cake WP concentration followed the same trend and increased significantly from sampling dates 1 to 4 for producers 2 and 3 (Fig. 2).

3.1. Conclusions

In the long run, the continued success and sustainability of broiler production may depend on how well the manure is managed and utilized. The new management practice (decaking) is an effort by poultry producers to reduce the quantity of manure produced for land application while gaining economic incentives such as less labor and expenditure. Our results showed, on as is basis, approximately 57% of the litter remains in the poultry house after decaking at the end of each growth cycle compared to 0% for total cleanout practice. No significant differences were observed between broiler cake and litter pH, TNP, inorganic nitrogen, TP, and water soluble phosphorus content. However, significant differences were observed in the cake and litter metals content. According to the Natural Resource Conservation Service (NRCS) Code 590, very little specific on-farm data are available on the characterization and nutrient composition of various manure types including broiler cake/litter. However, generalization of any con-

clusion from this study may not be appropriate, since the results represent information gained from only three producers, hence more studies are warranted.

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